ESTABLISHING PREDICTIVE SARS-COV-2 WASTEWATER SURVEILLANCE PROGRAM DURING THE COVID-19 PANDEMIC

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ACKNOWLEDGEMENT AND SIGNIFICANT CONTRIBUTORS

- Sample collection team
- Dr. Joan Rose and Rose Lab Team (Dr. Nishita D’Souza, Matthew Flood, Rebecca Ives, Samantha Carbonell)
- Michigan State University – Infrastructure, Planning and Facilities
- Natisha Foster - Michigan State University, Assistant Director for Coordination and Planning for Residence Education and Housing Services
- Michigan State University Surveillance Committee Taskforce – Early Detection Plan
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  - Michigan Department of Health and Human Services
  - Michigan State University
TAKE HOME MESSAGES

- Coordination and collaboration between multi-disciplinary teams is critical to use this tool for predictions.

- Data analysts and modelers are needed at the table with each group collecting each data stream to ensure interoperability.

- Identifying how the data will be used for decision making can guide the analysis and make the process more efficient.
BACKGROUND

- Clinically screening individuals for COVID-19 is resource and labor intensive
  - Limited practical application in many scenarios
- Monitoring wastewater is both passive and screens a larger population with fewer analytical tests
- SARS-CoV-2 shed in feces has not been found to cause infection through direct exposure to treated or untreated wastewater
- Methods were established for diseases like polio and still used to evaluate vaccine efficacy in some locations

National Wastewater Surveillance System (NWSS)
Dr. Joan Rose began monitoring in May 2020 at 4 sites.

Virus concentrations in sewage commensurate with cases/outbreak in E. Lansing.

Began to see positive signals in resident hall sewage as cases were confirmed.

In Fall 2021 MSU developed an Early Detection Program (EDP) that uses:
- Saliva samples
- Pooled testing

Expanded in Spring with a Pilot Study in conjunction with the EDP.

Source: Dr. Nishita Dsouza, Matthew Flood, Rebecca Ives, Dr. Joan B. Rose, Michigan State University (personal communication) DRAFT NOT FOR QUOTATION CITATION OR DISTRIBUTION
GOALS

- Develop a monitoring system for community level COVID-19 disease burden
- Establish relationships between wastewater monitoring concentrations and disease incidence
- Establish an early warning signal of spread and/or increases in community cases
- Support decision making for developing effective policies to mitigate spread
SAMPLE COLLECTION DESCRIPTION

- **ISCO 3700**
  - Composite sampler
  - Controller, battery, pump, cooler

- **Configuration**
  - 300 mL per aliquot
  - 15-minute frequency
  - 5AM-12PM
  - Twice weekly frequency
WASTEWATER SAMPLING DESCRIPTION

- Site Types
  - Single-building
  - Multi-Building

- Locations
  - 2021 Spring - 6 dorms
  - 2021 Summer - 3 dorms
  - 2021 Fall - 15 dorms
  - 3 off-campus community sites

- Analysis
  - ddPCR for SARS-CoV-2 (N1 & N2)
  - pH, temperature, turbidity
SUPPORTING DATA STREAMS

- Early Detection Program
  - Asymptomatic saliva-based weekly screening
  - Variables: daily new cases, rolling 7-day sum
- Residential Building Occupancy and Isolation Counts
  - New and continuing isolation counts daily
  - Isolation counts = clinical testing plus EDP
- Vaccination Status
  - Building-level
  - Starting 9/23/21
- Building-Level Water Use
  - Surrogate for wastewater volume and flow
Wastewater results generally track with isolation counts.
- Overall concentrations increase with the number of cases
- Variation between locations
Literature Suggests:

- Wastewater is correlated with case counts
- Wastewater signal precedes cases
- Infected people shed virus for less than 28 days

Serial Correlation

- Subset of autocorrelation
- Correlation between two time series
- Spearman’s rank correlation
EARLY WARNING - SERIAL CORRELATION - RESULTS

- Maximum correlation with cases two days after sampling - $\rho = 0.456$ ($p < 0.001$)
- Modest early warning
- Results are impacted by detection of asymptomatic cases before they would be identified through clinical or community-based health reporting
ENGINEERING AND MODELING CONSIDERATIONS

- Low flows or sampler malfunction occasionally require grab samples
- Buildings have different wastewater composition (cafeteria, laundry, Starbucks, etc.)
- Building design and wastewater conveyance
- Uncertainty in model form and parameters
  - Building vs. Campus vs. Community vs WWTP catchment
    - Hydraulic Residence Time (HRT)
    - Mixing
Several approaches to evaluate the data mechanistically emerged…

- **Per capita wastewater** \( (r_{\text{ww}}) \)
  - \( \text{L/person-day} \)
- **Viral shedding** \( (r_{\text{shed}}) \)
  - \( r_{\text{virus}} = \text{GC/g feces} \)
  - \( r_{\text{feces}} = \text{g feces/person-day} \)
  - \( r_{\text{shed}} = r_{\text{virus}} \times r_{\text{feces}} = \text{GC/day} \)

\[
C_{\text{WW}}[i] = \frac{\text{isolation}_{[i]} \times r_{\text{shed}}}{\text{population}_{[i]} \times r_{\text{ww}}}
\]

\[
\text{isolation}_{[i]} = \frac{C_{\text{WW}}[i] \times \text{population}_{[i]} \times r_{\text{ww}}}{r_{\text{shed}}}
\]

Assuming rate of wastewater shed is equal for all people
Assume rate of viral shed is positive and constant for infected population
POISSON REGRESSION – SEMI-MECHANISTIC MODEL FORM

\[ \text{isolation} \sim \text{pois}(\lambda) \]

- Occupancy/Population
- Location (as random effect)
- Isolation with early warning offset
- Wastewater quality parameters (temperature, turbidity, volume, etc.)

Spearman Correlation with SARS-CoV-2 Wastewater Concentrations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Correlation Coefficient</th>
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<tr>
<td>iso.cont.off</td>
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<td>iso.cont</td>
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<td>pos.roll</td>
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<tr>
<td>iso.new.</td>
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<tr>
<td>vol.daily</td>
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<td>iso.new</td>
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<td>ph</td>
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<td>turbidity</td>
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<td>positive</td>
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<td>vac.percent</td>
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<tr>
<td>temperature</td>
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</tbody>
</table>
INITIALS CONCLUSIONS

• Wastewater was a significant predictor of isolations with and without the serial correlation corrector

• Location differences were observed but limited date to converge random effects

• Normalization with building population does improve the model with the assumptions
FULL MODEL CONCLUSIONS

Occupancy, pH, and temperature had the largest influence on predictions followed by concentration and water usage (a surrogate for flow)

Significance

- $p < 0.001$: occupancy, pH, temperature – Building population, pH and temperature (grab vs composite)
- $p < 0.01$: conc.virus, vol.daily* - Concentration of virus and water usage
- $p > 0.05$: turbidity, vol.comp - Related to water usage (masked by vol.daily)
NEXT STEPS - RESEARCH

- Evaluate other mechanistic parameters and model forms (i.e. flow)
- No direct measurement but water usage (minute by minute)
- Stochastic model with variable shedding rates and excretion rates
- Determine predictability of wastewater signal for variants
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QUESTIONS???